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Research Article

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Effect of sources and levels of potassium in cotton as influenced fractions of soil potassium under vertisols in Vidarbha region of Maharashtra

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Summary

The present investigation was carried out in vertisols of Akola district of Maharashtra to ascertain the effect of potassium application on yield and quality of Bt cotton. This was carried out by conducting field experiments on research farm of Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola and similarly on five farmer's fields in intensive cotton growing area of vertisols in Akola district during 2012-13 and 2013-14. The treatments comprised of various levels of potassium (0, 25, 50 kg K_2O ha^{-1}) applied through either MOP or SOP and additional foliar sprays of SOP @1.5 per cent at critical growth stages of cotton alongwith addition of equivalent quantity of sulphur through bensulf and control without potassium. The fractions of soil potassium were found to be increased alongwith increasing levels of potassium. The reduction in fractions of soil potassium during peak growth stages suggests that there was highest uptake of potassium during this stage and supplemental foliar application of potassium (SOP) had significant response at critical growth stages. The vertisols of present investigation categorized as low to medium in sulphur. Application of sulphur @ 18 kg ha^{-1} through bensulf was also found equally beneficial as that of SOP for increasing yield. From the present investigation it can be concluded that the fractions of potassium in soil decreased at critical growth stages of cotton *viz.*, flowering and boll development due to increasing uptake by cotton. The application of potassium @ 50 kg K_2O ha^{-1} either through MOP or SOP irrespective of sources showed increase in soil potassium fractions and improvement in soil fertility.

Key words : Fractions of soil potassium, Nutrient mining, Soil fertility

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Introduction

Cotton is the most important fibre crop of India and backbone of our textile industry, accounting for 70 per cent of total fibre consumption in textile sector and 38 per cent of the country's export. Area under cotton cultivation in India (7.6 million ha) is highest in the worldand employs seven million people for their living. Cotton is a crop most suited to drylands and has flourished there despite the vagaries of nature and poor monsoons.

Table A : Farmer`s detail (2012)

RI	RII	RIII	RIV	RV
Anil Ingle	Anil Ingle	Pravin Ingle	Dilip Dhore	Gopal Dhore
Village: Changephal	Village: Changephal	Village: Changephal	Village: Alanda	Village: Alanda
Tehsil: Barshitakkli	Tehsil: Barshitakkli	Tehsil: Barshitakkli	Tehsil: Barshitakkli	Tehsil: Barshitakkli
Dist. Akola	Dist. Akola	Dist. Akola	Dist. Akola	Dist. Akola

Table B : Farmer`s detail (2013)

RI	RII	RIII	RIV	RV
Dilip Dhore	Anant Janorkar	Sunil Janorkar	Pradip Ingle	Anil Ingle
Village: Alanda	Village: Alanda	Village: Alanda	Village: Changephal	Village: Changephal
Tehsil: Barshitakkli	Tehsil: Barshitakkli	Tehsil: Barshitakkli	Tehsil: Barshitakkli	Tehsil: Barshitakkli
Dist. Akola	Dist. Akola	Dist. Akola	Dist. Akola	Dist. Akola

The cotton is mostly grown on black cotton soils, the typical swell-shrink soils of Deccan Plateau. The cotton crop is grown in the *Kharif* season and sowing is generally done with onset of monsoon. It is grown in the entire state except Konkan and Eastern Maharashtra. The main reason for low productivity of cotton in Maharashtra is its large scale rainfed cultivation (97%).

Potassium is required in large quantities by cotton, from 3 to 5 kg K ha^{-1} day^{-1} (Halevy, 1976). The total quantity of K taken up by the plant is related to the level of available soil- and fertilizer K (Bennett *et al.*, 1965 and Kerby and Adams, 1985) and yield demand of the crop. An average mature cotton crop is estimated to contain between 110 and 250 kg ha^{-1} of K, of which about 54 per cent is in the vegetative organs and 46 per cent is in the reproductive organs.

Most of the black soils were thought to be well supplied with K and thus, it was presumed that they do not need K application. However, in view of potential of newly released high yielding varieties of crops these soils may not be well supplied with K. In view of the high potassium content in swell shrink soils it was not the general practice to recommend potassium like regular application of N and P fertilizers. Among the major nutrients, potassium not only improves yields but also benefits various aspects of quality. Although the potassium content of vertisols and associated intergrades is high, many crops have been found to give good response to application of potassium. Most crops absorb as much or more K than they absorb N from the soil. The nutrient removal exceeds nutrient addition. Potash balance in Maharashtra is negative and mining of soil K reserves is going on at an alarming pace.

Resource and Research Methods

The present investigation was carried out by conducting field experiments on the research farm of Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola and similarly on five farmer's fieldsin intensive cotton growing area of Akola in vertisols during 2012-13 and 2013-14 (Table A and B).

Soils were processed (<2 mm) and analysed for pH (1:2.5 Soil water suspension), electrical conductivity, organic carbon, available nutrients (N, P, K and S) and NH_4OAc extractable K following standerd procedures (Jackson,1973). Non-exchangeable K was measured according to the procedure described by Knudsen and Peterson (1982) and total K with HF- $HClO_4$ digestion method (Lim and Jackson, 1982). Lattice K was calculated as the difference between the total and HNO_3 extractable K. Potassium in all the filtered extracts was measured by flame photometer.

Research Findings and Discussion

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Chemical properties of soils :

The soils of the present investigation are alkaline in pH (>7.5) (Table 1) and electrical conductivity varying between 0.24 to 0.26 and 0.33 to 0.38 dSm^{-1} (Table 2). The organic carbon content of the soils under present study conducted under typical vertisols of Akola district recorded the statistically significant increase with

Table 1 : Soil pH as influenced by potassium application

	Treatments	pH (1:2.5)			
		University farm		Farmer`s fields	
		2012-13	2013-14	2012-13	2013-14
T_1	Control K (0)	8.20	8.22	8.34	8.36
T_2	FP K_2O@25 kg ha^{-1} (MOP)	8.22	8.28	8.36	8.37
T_3	K_2O@ 50 kg ha^{-1} (MOP)	8.21	8.30	8.40	8.41
T_4	K_2O@ 50 kg ha^{-1} (SOP)	8.21	8.26	8.35	8.37
T_5	K_2O@ 50 kg ha^{-1} (MOP) + 2 srays (SOP)	8.21	8.29	8.37	8.38
T_6	K_2O@ 50 kg ha^{-1} (SOP)-+ 2 sprays (SOP)	8.21	8.31	8.41	8.42
T_7	2 Sprays @1.5 % (SOP)	8.22	8.29	8.38	8.40
T_8	K_2O@ 50 kg ha^{-1}(MOP) + S @ 18 kg ha^{-1}	8.20	8.25	8.39	8.36
	S.E.±	0.01	0.01	0.007	0.01
	C.D. (P=0.05)	NS	0.03	NS	0.03

NS= Non-significant

Table 2 : Soil electrical conductivity as influenced by potassium application

	Treatments	Electrical conductivity (dS m^{-1})			
		University farm		Farmer`s fields	
		2012-13	2013-14	2012-13	2013-14
T_1	Control K (0)	0.25	0.25	0.33	0.33
T_2	FP K_2O@25 kg ha^{-1} (MOP)	0.24	0.26	0.35	0.33
T_3	K_2O@ 50 kg ha^{-1} (MOP)	0.25	0.25	0.38	0.34
T_4	K_2O@ 50 kg ha^{-1} (SOP)	0.25	0.26	0.35	0.35
T_5	K_2O@ 50 kg ha^{-1} (MOP) + 2 sprays (SOP)	0.26	0.26	0.36	0.33
T_6	K_2O@ 50 kg ha^{-1} (SOP) + 2 sprays (SOP)	0.25	0.25	0.35	0.36
T_7	2 Sprays @1.5 % (SOP)	0.24	0.25	0.33	0.36
T_8	K_2O@ 50 kg ha^{-1} (MOP) + S @ 18 kg ha^{-1}	0.24	0.27	0.33	0.34
	S.E.±	0.01	0.01	0.01	0.01
	C.D. (P=0.05)	NS	NS	NS	NS

NS= Non-significant

Table 3 : Soil organic carbon content as influenced by potassium application

	Treatments	Organic carbon (g kg^{-1})			
		University farm		Farmer`s fields	
		2012-13	2013-14	2012-13	2013-14
T_1	Control K (0)	4.90	4.88	4.80	4.79
T_2	FP K_2O@25 kg ha^{-1} (MOP)	4.93	4.94	5.24	5.23
T_3	K_2O@ 50 kg ha^{-1} (MOP)	5.13	5.10	5.44	5.43
T_4	K_2O@ 50 kg ha^{-1} (SOP)	5.06	5.06	5.46	5.46
T_5	K_2O@ 50 kg ha^{-1} (MOP) + 2 sprays (SOP)	5.16	5.14	5.64	5.65
T_6	K_2O@ 50 kg ha^{-1} (SOP) + 2 sprays (SOP)	5.10	5.09	5.60	5.60
T_7	2 Sprays @1.5 % (SOP)	5.07	5.07	5.40	5.43
T_8	K_2O@ 50 kg ha^{-1} (MOP) + S @ 18 kg ha^{-1}	5.01	5.02	5.30	5.34
	S.E.±	0.10	0.01	0.12	0.01
	C.D. (P=0.05)	NS	0.04	0.35	0.03

NS= Non-significant

increase in levels of application of potassium (Table 3). This reveals that the potassium application played important role in increasing biomass of the cotton and ultimately caused addition of more dry matter over control plots which is without potassium application during both the years at university farm and farmer's fields. This may be due to the fact that the treated plots produced more dry matter compared to the control plots (Krishnan and Lourduraj, 1997).

There is slight numerical increase in available nitrogen (Table 4) under application of 50 kg K_2O ha^{-1} through either MOP or SOP plus supplemental foliar application of potassium through SOP thus, indicating the beneficial effect of additional sprayings at critical growth stages. Inspite of application of equivalent quantity of sulphur through bensulf along with potassium through MOP (T_8) also had increasing values than that of under control without potassium (T_1). The overall balance of nitrogen is recorded under different treatments of potassium over the initial soil available nitrogen at both the sites during the entire growing period of cotton. This reveals that increased available N content might be due to synergetic effect of potassium application resulted in increasing nitrogen availability in soil, as it is known that there is a favourable effect of potassium application on available nitrogen status of soil (Srinivasarao *et al*., 2000). Thus, this is largely due to balanced supply of potassium alongwith N and P.

Among the various treatments available P (Table 5) was significantly higher under K@ 50 kg ha^{-1} (MOP) + 2 sprays (SOP) (T_5) during both the years at university farm and farmer's field over the control. Similarly it has been also reported that the treatment receiving only 2 sprays of SOP was at par with control. This reveals that in case of only sprays the phosphorus acts mutually with potassium and further reveals the need of potassium

Table 4 : Soil available nitrogen as influenced by potassium application

	Treatments	Available nitrogen (kg ha^{-1})			
		University farm		Farmer`s fields	
		2012-13	2013-14	2012-13	2013-14
T_1	Control K (0)	261.4	258.4	259.6	265.5
T_2	FP K_2O@25 kg ha^{-1} (MOP)	250.0	259.8	285.6	267.4
T_3	K_2O@ 50 kg ha^{-1} (MOP)	264.5	266.5	317.3	269.5
T_4	K_2O@ 50 kg ha^{-1} (SOP)	253.9	264.4	294.8	271.7
T_5	K_2O@ 50 kg ha^{-1} (MOP) + 2 sprays (SOP)	264.9	268.5	336.1	273.0
T_6	K_2O@ 50 kg ha^{-1} (SOP) + 2 sprays (SOP)	265.7	268.7	296.8	275.8
T_7	2 Sprays @1.5 % (SOP)	237.7	253.4	279.1	269.9
T_8	K_2O@ 50 kg ha^{-1} (MOP) + S @ 18 kg ha^{-1}	240.1	260.8	281.5	272.6
	S.E.±	5.80	1.12	6.76	1.19
	C.D. (P=0.05)	17.60	3.40	19.58	3.44

Table 5 : Soil available phosphorus content as influenced by potassium application

	Treatments	Available phosphorus (kg ha^{-1})			
		University farm		Farmer`s fields	
		2012-13	2013-14	2012-13	2013-14
T_1	Control K (0)	12.91	13.56	29.66	29.73
T_2	FP K_2O@25 kg ha^{-1} (MOP)	13.42	13.76	30.20	30.25
T_3	K_2O@ 50 kg ha^{-1} (MOP)	14.11	13.82	30.72	30.74
T_4	K_2O@ 50 kg ha^{-1} (SOP)	13.64	13.85	30.38	30.34
T_5	K_2O@ 50 kg ha^{-1} (MOP) + 2 sprays (SOP)	14.38	14.42	31.18	31.84
T_6	K_2O@ 50 kg ha^{-1} (SOP) + 2 sprays (SOP)	13.85	14.15	30.88	30.89
T_7	2 Sprays @1.5 % (SOP)	13.47	13.58	30.44	30.44
T_8	K_2O@ 50 kg ha^{-1} (MOP) + S @ 18 kg ha^{-1}	13.39	13.72	30.34	30.35
	S.E.±	0.25	0.14	0.12	0.01
	C.D. (P=0.05)	0.77	0.43	0.36	0.03

application. The data pertaining to soil available potassium (Table 6) noted the increasing levels of potassium caused significant increase in trend. The lowest soil available potassium was recorded at control K (0) (T_1) where only N and P was applied without any potassium application. Application of K@ 25 kg K_2O ha^{-1} under farmer's practice (T_2) further increased in available K during both the years of study. Application of 50 kg K_2O ha^{-1} has further increased the available potassium statistically over control indicating that equivalent potassium fertilizer requirement for a unit increase in available potassium (Arvind and Muthuswamy, 1983).

The available sulphur recorded a statistically significant increase in trend alongwith increase in levels of potassium during both the years of investigation at both sites. The sources of sulphur *viz.*, SOP and bensulf under study recorded significant increase than that of the treatments without addition of sulphur which can be attribtuted to the supply of sulphur indicating necessity of maintaining sulphur status of the vertisols and additional benefits from secondary nutrient that of sulphur.

Fractions of soil potassium :

Water soluble K :

The water soluble K in Vertisols under study (Table 7 and 8) revealed that the water soluble potassium at 50

Table 6 : Soil available potassium content as influenced by potassium application

	Treatments	Available potassium (kg ha^{-1})			
		University farm		Farmer`s fields	
		2012-13	2013-14	2012-13	2013-14
T_1	Control K (0)	339.7	341.8	429.8	431.5
T_2	FP K_2O@25 kg ha^{-1} (MOP)	365.9	367.1	443.9	445.7
T_3	K_2O@ 50 kg ha^{-1} (MOP)	395.7	397.7	460.5	462.3
T_4	K_2O@ 50 kg ha^{-1} (SOP)	377.1	378.6	452.7	453.5
T_5	K_2O@ 50 kg ha^{-1} (MOP) + 2 sprays (SOP)	418.1	420.9	475.7	477.6
T_6	K_2O@ 50 kg ha^{-1} (SOP) + 2 sprays (SOP)	390.1	392.6	462.1	464.1
T_7	2 Sprays @1.5 % (SOP)	362.2	364.4	445.9	447.4
T_8	K_2O@ 50 kg ha^{-1} (MOP) + S @ 18 kg ha^{-1}	362.1	364.1	449.5	451.7
	S.E.±	8.07	0.53	2.73	0.61
	C.D. (P=0.05)	24.49	1.61	7.91	1.76

Table 7 : Water soluble potassium at 50 per cent boll bursting stage of cotton

	Treatments	University farm				Farmer`s fields			
		Water soluble potassium (mg kg^{-1})							
		2012-13	2013-14	Pooled	% reduction over harvest	2012-13	2013-14	Pooled	% reduction over harvest
T_1	Control K (0)	7.69	6.83	7.26	86.63	7.47	9.25	8.36	88.93
T_2	Farmer's practice K@25 kg ha^{-1} (MOP)	8.25	6.84	7.55	89.56	7.57	9.54	8.55	87.69
T_3	K@ 50 kg ha^{-1}(MOP)	9.37	8.22	8.79	88.78	8.27	9.87	9.07	86.71
T_4	K@ 50 kg ha^{-1}(SOP)	8.96	7.57	8.26	91.37	8.16	9.72	8.94	88.07
T_5	K@ 50 kg ha^{-1} (MOP) + 2 sprays (SOP)	9.74	8.47	9.10	90.18	9.47	10.21	9.84	92.39
T_6	K@ 50 kg ha^{-1} (SOP) + 2 sprays (SOP)	9.18	7.95	8.56	87.52	8.68	10.01	9.35	88.70
T_7	2 Sprays @1.5 % (SOP)	8.55	7.37	7.96	89.53	7.94	9.69	8.82	89.54
T_8	K@ 50 kg ha^{-1} (MOP) + S @ 18 kg ha^{-1}	8.84	7.44	8.14	90.84	8.10	9.65	8.88	90.15
	S.E.±	0.10	0.06	0.12		0.03	0.05	0.06	
	C.D. (P=0.05)	0.32	0.18	0.37		0.09	0.16	0.18	

per cent boll bursting stage and at harvest of cotton on both university farm and farmer's fields differed significantly and it was comparatively low under control K (0) (T_1), farmer's practice K@25 kg ha^{-1} (MOP) (T_2) and onlyfoliar application two sprays @1.5 % (SOP) (T_7) with no soil application of potassium. It was further observed that water soluble potassium was lower at 50 per cent boll bursting stage as compared to the water soluble potassium at harvest stage under all the treatments in study. The average water soluble potassium was observe to be decreased by 86.63 to 91.37 (university farm) and 88.07 to 92.39 (farmer's fields) per cent at 50 per cent boll bursting stage over the values at harvest stage indicating that more potassium has been used at peak growth period. The lower values of water soluble potassium at 50 per cent boll bursting stage can be attributed to the increasing potassium uptake by cotton at critical growth stages.Potassium present in soil solution as soluble cation is termed as water soluble K which is readily adsorbed by the plants and relatively unbound by cation exchange forces and invariably subject to leaching losses in relation to soil properties (Ramamoorthy and Velayutham, 1976). The significantly higher water soluble potassium was recored under all the treatments receiving potassium over control at long term fertilizer experiment IARI, New Delhi (Brijlal *et al.*, 2004). Similar values of water soluble potassium have been recorded for the swell-shrink soils of Sayala and Barshi series in Maharashtra (Patil and Sonar, 1993).

Exchangeable K :

The exchangeable potassium (Table 9 and 10) was comparatively lower at 50 per cent boll bursting stage of cotton in comparison with the values at harvest stage. It was also observed that the exchangeable potassium was increased along with the increase in potassium levels

Table 8 : Water soluble potassium at harvest stage of cotton as influenced by potassium application

	Treatments	University farm			Farmer`s fields		
		Water soluble potassium (mg kg^{-1})					
		2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
T_1	Control K (0)	7.85	8.77	8.38	8.49	10.28	9.40
T_2	Farmer's practice K@25 kg ha^{-1} (MOP)	7.87	8.84	8.43	8.83	10.64	9.75
T_3	K@ 50 kg ha^{-1}(MOP)	9.44	10.22	9.90	9.91	10.97	10.46
T_4	K@ 50 kg ha^{-1}(SOP)	8.37	9.57	9.04	9.45	10.82	10.15
T_5	K@ 50 kg ha^{-1} (MOP) + 2 sprays (SOP)	9.57	10.47	10.09	9.96	11.31	10.65
T_6	K@ 50 kg ha^{-1} (SOP) + 2 aprays (SOP)	9.47	9.95	9.78	9.93	11.11	10.54
T_7	2 Sprays @1.5 % (SOP)	8.27	9.37	8.89	8.86	10.79	9.85
T_8	K@ 50 kg ha^{-1} (MOP) + S @ 18 kg ha^{-1}	8.33	9.44	8.96	8.91	10.75	9.85
	S.E.±	0.04	0.05	0.07	0.02	0.05	0.05
	C.D. (P=0.05)	0.11	0.17	0.20	0.06	0.14	0.15

Table 9 : Exchangeable potassium at 50 per cent boll bursting stage of cotton as influenced by potassium application

	Treatments	University farm			Farmer's fields		
		Exchangeable potassium (mg kg^{-1})					
		2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
T_1	Control K (0)	153.52	155.61	154.56	175.02	179.06	177.04
T_2	Farmer's practice K@25 kg ha^{-1} (MOP)	161.89	163.77	162.83	184.34	188.04	186.19
T_3	K@ 50 kg ha^{-1}(MOP)	172.57	174.44	173.50	196.25	199.95	198.10
T_4	K@ 50 kg ha^{-1}(SOP)	165.36	167.23	166.30	193.70	197.40	195.55
T_5	K@ 50 kg ha^{-1} (MOP) + 2 sprays (SOP)	174.03	175.91	174.97	198.66	202.36	200.51
T_6	K@ 50 kg ha^{-1} (SOP) + 2 sprays (SOP)	172.84	174.71	173.77	197.76	201.46	199.61
T_7	2 Sprays @1.5 % (SOP)	162.46	164.33	163.39	185.87	189.57	187.72
T_8	K@ 50 kg ha^{-1} (MOP) + S @ 18 kg ha^{-1}	163.51	165.38	164.44	188.81	192.51	190.66
	S.E.±	0.43	0.42	0.60	0.51	0.54	0.75
	C.D. (P=0.05)	1.31	1.27	1.82	1.47	1.57	2.16

and it was significantly lower under control K (0) (T_1), farmer's practice K@25 kg ha^{-1} (MOP) (T_2) and only foliar application of two sprays @1.5 % (SOP) (T_7). This suggests that more potassium is being used at peak growth period of cotton. The concentration of potassium increases with application of fertilizer potassium, K^+ may get into the expanded interlayer space and become fixed, by reversing the weathering process. In soil solutions,

Table 10 : Exchangeable potassium at harvest stage of cotton as influenced by potassium application

	Treatments	University farm			Farmer's fields		
		Exchangeable potassium (mg kg^{-1})					
		2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
T_1	Control K (0)	155.90	163.20	159.55	178.86	181.09	179.97
T_2	Farmer's practice K@25 kg ha^{-1} (MOP)	164.93	167.55	166.24	185.52	186.69	186.11
T_3	K@ 50 kg ha^{-1}(MOP)	176.21	178.83	177.52	195.79	196.96	196.38
T_4	K@ 50 kg ha^{-1}(SOP)	174.97	177.59	176.28	191.43	192.60	192.01
T_5	K@ 50 kg ha^{-1} (MOP) + 2 sprays (SOP)	177.92	180.54	179.23	203.58	204.75	204.16
T_6	K@ 50 kg ha^{-1} (SOP) + 2 sprays (SOP)	176.74	179.36	178.05	197.18	198.35	197.77
T_7	2 Sprays @1.5 % (SOP)	172.48	175.10	173.79	187.23	188.40	187.81
T_8	K@ 50 kg ha^{-1} (MOP) + S @ 18 kg ha^{-1}	172.73	175.35	174.04	190.24	191.41	190.82
	S.E.±	0.68	1.99	2.10	0.62	0.65	0.90
	C.D. (P=0.05)	2.06	6.04	6.38	1.80	1.89	2.60

Table 11: Non- exchangeable potassium at 50 per cent boll bursting stage of cotton

	Treatments	University farm			Farmer's fields		
		Non exchangeable potassium (mg kg^{-1})					
		2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
T_1	Control K (0)	746.22	751.77	749.00	755.69	756.70	756.20
T_2	Farmer's practice K@25 kg ha^{-1} (MOP)	755.44	757.44	756.44	762.55	763.56	763.05
T_3	K@ 50 kg ha^{-1}(MOP)	826.34	828.34	827.34	773.39	774.40	773.89
T_4	K@ 50 kg ha^{-1}(SOP)	819.69	821.69	820.69	772.81	773.82	773.31
T_5	K@ 50 kg ha^{-1} (MOP) + 2 sprays (SOP)	829.25	831.25	830.25	864.94	865.95	865.44
T_6	K@ 50 kg ha^{-1} (SOP) + 2 sprays (SOP)	827.90	829.90	828.90	843.23	846.67	844.95
T_7	2 Sprays @1.5 % (SOP)	816.80	818.80	817.80	767.17	768.18	767.67
T_8	K@ 50 kg ha^{-1} (MOP) + S @ 18 kg ha^{-1}	818.57	820.57	819.57	769.51	770.52	770.02
	S.E.±	0.95	1.60	1.86	6.87	6.88	9.72
	C.D. (P=0.05)	2.89	4.86	5.65	19.89	19.92	28.15

Table 12 : Non- exchangeable potassium at harvest stage of cotton as influenced by potassium application

	Treatments	University farm			Farmer's fields		
		Non-exchangeable potassium (mg kg^{-1})					
		2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
T_1	Control K (0)	769.83	753.23	761.53	856.88	859.28	858.08
T_2	Farmer's practice K@25 kg ha^{-1} (MOP)	773.33	756.73	765.03	866.93	869.33	868.13
T_3	K@ 50 kg ha^{-1}(MOP)	856.50	839.90	848.20	914.63	917.03	915.83
T_4	K@ 50 kg ha^{-1}(SOP)	843.51	829.67	836.59	911.11	913.51	912.31
T_5	K@ 50 kg ha^{-1} (MOP) + 2 sprays (SOP)	860.27	843.67	851.97	951.33	953.73	952.53
T_6	K@ 50 kg ha^{-1} (SOP) + 2 sprays (SOP)	858.52	841.92	850.22	936.03	940.43	938.23
T_7	2 Sprays @1.5 % (SOP)	831.35	814.75	823.05	894.02	896.42	895.22
T_8	K@ 50 kg ha^{-1} (MOP) + S @ 18 kg ha^{-1}	836.72	820.12	828.42	900.91	903.31	902.11
	S.E.±	0.76	1.12	1.35	1.22	1.19	1.70
	C.D. (P=0.05)	2.30	3.39	4.10	3.53	3.44	4.93

the dominant cation is generally Ca^{2+} whose hydrated form is bigger than K^+, it enlarges the interlayer spaces, releasing more K^+., therefore, when exchange place with K^+, in the process when the potassium is removed from soil solution, consequent to crop and plant uptake, more potassium continues to be released from clay minerals by cation (including proton) exchange and a gradient created which diffuses out K^+ from within the structure of clay particles to their surface (Sekhon, 1999).

Exchangeable K content of swell-shrink soils of different agro-climatic zones in Western Maharashtra ranged from 140 to 390 mg kg^{-1} (Patil and Sonar, 1993). The exchangeable K content of Akola vertisols is reported by Ravankar *et al*. (2003) which was varied from (88.56 to194.51 mg kg^{-1}). Increase in exchangeable potassium under continuous application of NPK by 21 to 27 per cent over control has been recorded by Dhanokar *et al.* (1994) under LTFE study in vertisols.

Non-exchangeable K :

The non- exchangeable potassium (Table 11 and 12) was observed to be increased along with the levels of potassium fertilizer added. Similarly the non-exchangeable potassium was also increased under supplementary foliar application of potassium which is beneficial for the growth of plant during the flowering and boll development stages resulting into increased absorption of potassium that simultaneously depleted water soluble and exchangeable potassium levels thus, to replenish the need by more release of non-exchangeable potassium. The contribtion of non-exchangeable K to crops was relatively more in untreated plots than those receiving fertilizers K and there was close relationship between K in crops and non-

Table 13 : Lattice potassium at 50 per cent boll bursting stage of cotton as influenced by potassium application

	Treatments	University farm			Farmer's fields		
		Lattice potassium (mg kg^{-1})					
		2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
T_1	Control K (0)	11908.41	11904.32	11906.37	14698.05	14692.73	14695.39
T_2	Farmer's practice K@25 kg ha^{-1} (MOP)	11989.98	11990.21	11990.09	14712.35	14707.17	14709.76
T_3	K@ 50 kg ha^{-1}(MOP)	13611.04	13611.02	13611.03	15854.78	15849.96	15852.37
T_4	K@ 50 kg ha^{-1}(SOP)	13417.29	13417.51	13417.40	14872.55	14867.78	14870.16
T_5	K@ 50 kg ha^{-1} (MOP) + 2 sprays (SOP)	15100.73	15100.83	15100.78	17480.51	17476.56	17478.54
T_6	K@ 50 kg ha^{-1} (SOP) + 2 sprays (SOP)	13774.14	14116.09	13945.12	16820.59	16930.28	16875.44
T_7	2 Sprays @1.5 % (SOP)	13169.75	13169.75	13169.75	14723.09	14718.13	14720.61
T_8	K@ 50 kg ha^{-1} (MOP) + S @ 18 kg ha^{-1}	13390.38	13390.61	13390.50	14772.80	14768.04	14770.42
	S.E.±	17.20	124.65	125.83	76.40	84.94	114.25
	C.D. (P=0.05)	52.16	378.07	381.65	221.32	246.07	330.96

Table 14 : Lattice potassium at harvest stage of cotton as influenced by potassium application

	Treatments	University field			Farmer's field		
		Lattice potassium (mg kg^{-1})					
		2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
T_1	Control K (0)	12881.65	11943.90	12412.78	16217.65	14569.75	15393.70
T_2	Farmer's practice K@25 kg ha^{-1} (MOP)	13001.53	12024.99	12513.26	16214.56	14687.70	15451.13
T_3	K@ 50 kg ha^{-1}(MOP)	14907.36	13931.03	14419.20	17690.54	16164.42	16927.48
T_4	K@ 50 kg ha^{-1}(SOP)	14553.36	13573.85	14063.60	17606.59	16080.17	16843.38
T_5	K@ 50 kg ha^{-1} (MOP) + 2 sprays (SOP)	15568.40	14591.94	15080.17	18163.22	16636.81	17400.02
T_6	K@ 50 kg ha^{-1} (SOP) + 2 sprays (SOP)	15468.81	14492.78	14980.80	18084.20	16555.96	17320.08
T_7	2 Sprays @1.5 % (SOP)	14494.51	13517.85	14006.18	17567.96	16040.98	16804.47
T_8	K@ 50 kg ha^{-1} (MOP) + S @ 18 kg ha^{-1}	14528.20	13551.53	14039.87	17605.80	16078.91	16842.36
	S.E.±	112.25	109.89	157.09	44.69	15.91	47.44
	C.D. (P=0.05)	340.48	333.32	476.47	129.47	46.10	137.43

exchangeable K release from soil (Ganeshamurthy and Biswas, 1985).

Many studies explained the fact of substantial contribution of non- exchangeable K in plant K nutrition and soil K fertility management especially under continuous cropping in absence of K inputs (Srinivasarao *et al*., 1999 and 2001). Dhillon *et al*. (1987) revealed that the pattern of non- exchangeable K at different depths and it was higher in sub- surface soils compared to the surface soils. This might be due to release of fixed K to compensate the removal of water soluble K and exchangeable K by plants. Sen and Ghosh (2002) found that greater depletion of non- exchangeable potassium in the vertisol was due to the lowest initial non-exchangeable potassium content in these soils and dominance of montmorillonite group of minerals. In a present study little decline in non-exchangeable K was observed under control K (0) (T_1) and application of 25 kg K_2O ha^{-1} under farmer's practice (T_2) which reveals that K is mined from this fraction when K is not sufficiently applied, which is also reflected in total K (Singh *et al*., 2013).

Lattice K :

In view of the data pertaining to lattice potassium (Table 13 and 14) found to be comparatively higher at harvest stage than that of peak growth period. Further it becomes apparent from the data that increasing values of lattice potassium under addition of potassium fertilizers. Substantial release of lattice bound potassium during the period of plant growth could take place especially when no potassium or inadequate amount of it is supplied, in order to fulfil the demand of the crop (Ram and Prasad, 1983).

Total K :

The soils of the present investigation showed the

Table 15: Total potassium at 50 per cent boll bursting stage of cotton as influenced by potassium application

	Treatments	University farm			Farmer's fields		
		Total potassium (mg kg^{-1})					
		2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
T_1	Control K (0)	12815.83	12818.53	12817.18	15636.23	15637.73	15636.98
T_2	Farmer's practice K@25 kg ha^{-1} (MOP)	12915.55	12918.25	12916.90	15666.81	15668.31	15667.56
T_3	K@ 50 kg ha^{-1}(MOP)	14619.31	14622.01	14620.66	16832.68	16834.18	16833.43
T_4	K@ 50 kg ha^{-1}(SOP)	14411.30	14414.00	14412.65	15847.21	15848.71	15847.96
T_5	K@ 50 kg ha^{-1} (MOP) + 2 sprays (SOP)	16113.75	16116.45	16115.10	18553.58	18555.08	18554.33
T_6	K@ 50 kg ha^{-1} (SOP) + 2 sprays (SOP)	14784.06	15128.65	14956.36	17870.27	17988.42	17871.02
T_7	2 Sprays @1.5 % (SOP)	14157.55	14160.25	14158.90	15684.06	15685.56	15684.81
T_8	K@ 50 kg ha^{-1} (MOP) + S @ 18 kg ha^{-1}	14381.31	14384.01	14382.66	15739.22	15740.72	15739.97
	S.E.±	16.70	124.25	125.36	75.44	84.31	106.68
	C.D. (P=0.05)	50.65	376.86	380.25	218.52	244.22	309.04

Table 16 : Total potassium at grand growth stage of cotton as influenced by potassium application

	Treatments	University field			Farmer's field		
		Total potassium (mg kg^{-1})					
		2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
T_1	Control K (0)	13815.23	12869.28	13342.26	17261.87	15620.43	16441.15
T_2	Farmer's practice K@25 kg ha^{-1} (MOP)	13947.66	12958.26	13452.96	17275.84	15754.40	16515.12
T_3	K@ 50 kg ha^{-1}(MOP)	15949.52	14960.12	15454.82	18810.87	17289.43	18050.15
T_4	K@ 50 kg ha^{-1}(SOP)	15580.21	14590.81	15085.51	18718.58	17197.14	17957.86
T_5	K@ 50 kg ha^{-1} (MOP) + 2 sprays (SOP)	16616.16	15626.76	16121.46	19328.08	17806.64	18567.36
T_6	K@ 50 kg ha^{-1} (SOP) + 2 sprays (SOP)	16513.54	15524.14	16018.84	19227.34	17705.90	18466.62
T_7	2 Sprays @1.5 % (SOP)	15506.61	14517.21	15011.91	18658.07	17136.63	17897.35
T_8	K@ 50 kg ha^{-1} (MOP) + S @ 18 kg ha^{-1}	15545.99	14556.59	15051.29	18705.85	17184.41	17945.13
	S.E.±	112.05	109.52	156.68	44.93	16.21	47.76
	C.D. (P=0.05)	339.86	332.19	475.24	130.14	46.94	138.35

presence of higher total potassium (Table 15 and 16) under the application of potassium fertilizers. However, the lower values of total potassium were recorded under no or inadequate application of potassium fertilizer. The higher total K was recorded under K@ 50 kg ha^{-1} (MOP) + 2 sprays (SOP) T_5, (16121.46 to 18567.36 mg kg^{-1}). It was found 82.76 per cent more over control Ko (T_1) which is followed by K@ 50 kg ha^{-1} (SOP) + 2 sprays (SOP). Significantly lowest value of total K was recorded under control Ko and farmer's practice K@25 kg ha^{-1} (MOP) (13342.26 to 13452.96 mg kg^{-1}). The total potassium was observed to be increased along with the levels of potassium fertilizer added.

Relationship among the fractions of soil potassium:

The present investigation under true vertisols of Akola districts found that the different fractions of soil potassium (water soluble, exchangeable, non-exchangeable, lattice and total potassium exists a significant positive correlation among them (Table 17 and 18) at both university farm and farmer's fields.

Further this has been also recorded that there is positive correlation between non-exchangeable potassium and lattice potassium indicated a dynamic equilibrium existing between these two forms. Moreover, exchangeable potassium was positively correlated with total potassium indicating that fractions of the total potassium in available form increased along with the increase in total potassium in soil (Das *et al*., 1997). Smectitevertisols and associated soils, with high clay content and with mica as an associated clay mineral with larger surface area and cation exchange capacity, showed

Table 17 : Relationship among different forms of soil potassium at university farm

Fractions of soil potassium	Water soluble K		Exchangeable K		Non- exchangeable K		Lattice K		Total K	
	Peak growth stage	Grand growth stage	Peak growth stage	Grand growth stage	Peak growth stage	Grand growth stage	Peak growth stage	Grand growth stage	Peak growth stage	Grand growth stage
WSK peak growth	1									
WSK grand growth	0.97**	1								
Ex. K peak growth	0.95**	0.94**	1							
Ex. K grand growth	0.92**	0.85**	0.90**	1						
NEK peak growth	0.87**	0.81**	0.80**	0.96**	1					
NEK grand growth	0.92**	0.88**	0.86**	0.96**	0.98**	1				
LK peak growth	0.95**	0.91**	0.86**	0.89**	0.87**	0.90**	1			
LK grand growth	0.93**	0.91**	0.88**	0.95**	0.95**	0.97**	0.95**	1		
TK peak growth	0.95**	0.91**	0.86**	0.89**	0.88**	0.91**	0.99**	0.95**	1	
TK grand growth	0.93**	0.91**	0.88**	0.95**	0.96**	0.98**	0.95**	0.99**	0.96**	1

** indicates significance of value at P=0.01

Table 18 : Relationship among different forms of soil potassium at farmer`s fields

Fractions of soil potassium	Water soluble K		Exchangeable K		Non- exchangeable K		Lattice K		Total K	
	Peak growth stage	Grand growth stage	Peak growth stage	Grand growth stage	Peak growth stage	Grand growth stage	Peak growth stage	Grand growth stage	Peak growth stage	Grand growth stage
WSK peak growth	1									
WSK grand growth	0.92**	1								
Ex. K peak growth	0.88**	0.97**	1							
Ex. K grand growth	0.97**	0.96**	0.95**	1						
NEK peak growth	0.92**	0.80**	0.71**	0.84**	1					
NEK grand growth	0.97**	0.94**	0.94**	0.97**	0.85**	1				
LK peak growth	0.91**	0.87**	0.76**	0.88**	0.95**	0.85**	1			
LK grand growth	0.86**	0.84**	0.88**	0.86**	0.68**	0.94**	0.67**	1		
TK peak growth	0.92**	0.87**	0.76**	0.88**	0.95**	0.86**	0.99**	0.67**	1	
TK grand growth	0.86**	0.85**	0.88**	0.87**	0.69**	0.94**	0.68**	0.99**	0.68**	1

** indicate significance of value at P=0.01

higher exchangeable potassium. No much variation in all the forms of potassium was observed. This may be due to the replenishment of exchangeable potassium by non-exchangeable potassium, consequent upon crop removal. This shows that changes in available potassium reflect the decline in total soil potassium (Hirekurabar *et al*., 2000). Pal and Mukhopadhay (1990) noted the significant association of finer textural component of soils particularly that of clay fraction with different forms of potassium in the soil. All the forms of potassium showed positive trend of correlation among themselves largely corroborating the well-known concept of existence of a dynamic equilibrium among different forms of potassium in soil through which potassium supply to the roots of crop plants are directly or indirectly ensured.

Conclusion :

From the present investigation it can be concluded that the fractions of potassium decreased at critical growth stages of cotton *viz.*, flowering and boll development due to increasing uptake by cotton. The application of potassium @ 50 kg K_2O ha^{-1} either through MOP or SOP irrespective of sources showed increase in soil potassium fractions and improvement in soil fertility.

The cultivation of cotton without K application resulted into mining of K reflected in reduction of water soluble, exchangeable and non- exchangeable K due to inability to buffer the various pools of K which ultimately could not fulfill the need of cotton adequately. Application of potassium in conjunction with nitrogen and phosphorus showed beneficial effect on various forms of potassium in soil and consequently their synergistic effect on availability and utilization of nutrients by crop.

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